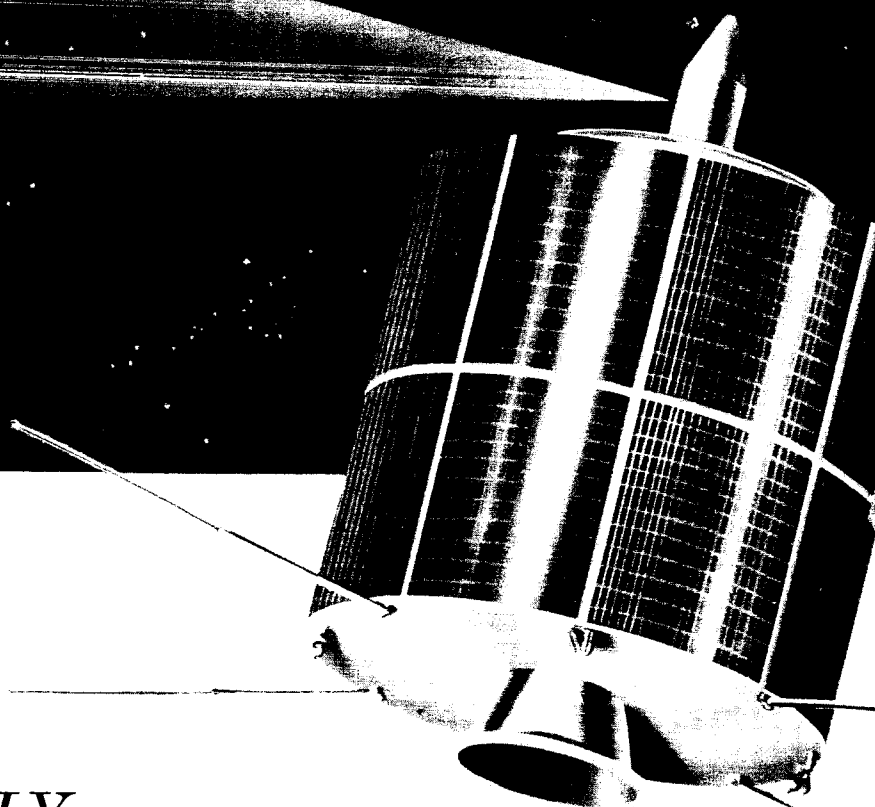
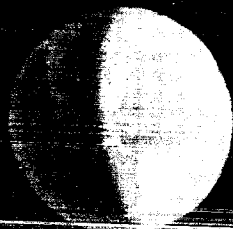


Advanced SYNCOM



October 1962

MONTHLY PROGRESS REPORT

NASA Contract 5-2797
SSD 2537R

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CULVER CITY, CALIFORNIA

15 November 1962

SUBJECT: Advanced Syncom Monthly Progress Report
for October 1962

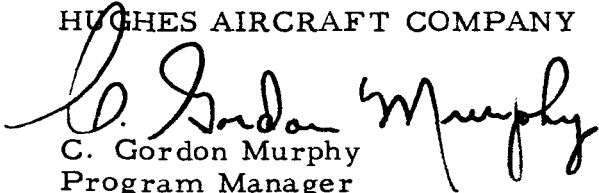
TO: Mr. Alton E. Jones
Program Manager, Syncom
Goddard Space Flight Center
Code 621
Greenbelt, Maryland

Attached are copies of the Advanced Syncom Monthly Progress Report for October 1962.

The first 4-kmc developmental traveling-wave tube was tested during the report period with very encouraging results. Static pattern measurements of a 16-element array of 4-kmc vertically polarized transmitting elements indicate that the array gain will nearly achieve the 18 db predicted analytically.

Procurement action was initiated for the hot gas control system through the issuance of a request for proposal to ten bidders. Specifications for a solid-propellant apogee injection rocket motor were forwarded to Goddard Space Flight Center for use in the NASA procurement of this motor.

HUGHES AIRCRAFT COMPANY


C. Gordon Murphy
Program Manager
Project Syncom

cc: H. E. Tetirick
Goddard Space Flight Center
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Advanced SYNCOM

October 1962

MONTHLY PROGRESS REPORT

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*NASA Contract 5-2797
SSD 2537R*

AEROSPACE GROUP
SPACE SYSTEMS DIVISION
HUGHES AIRCRAFT COMPANY
CULVER CITY, CALIFORNIA

HUGHES

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1. INTRODUCTION

Under NASA Goddard Space Flight Center Contract NAS-5-2797, Hughes Aircraft Company is conducting feasibility studies and advanced technological development for an advanced, stationary, active repeater, communication satellite.

An Initial Project Development Plan, submitted to Goddard on 15 August 1962, reported the initial system feasibility studies and delineated technical approaches, the administrative plan, manpower requirements, schedule, and funding considerations appropriate for accomplishing the NASA contract objectives.

These monthly technical letter reports present the technical progress made during the reporting period, the critical problems or delays encountered, and the plans for the forthcoming reporting period.

Separate reports of schedule status are provided through biweekly PERT reports. Monthly financial management reports provide the funding status.

2. SYSTEM DESIGN STUDY

Coordination with Lenkurt Electric Co., Inc., was initiated to provide detailed spacecraft design requirements for inclusion in the specifications of the two ground station components under study by Lenkurt. Additional studies were completed in the systems reliability design and analysis program. Effort was continued to minimize the number of different component types employed in the design of Syncom II.

COMMUNICATION SYSTEM

On 5 October 1962, a technical conference was conducted with participation by representatives of Goddard Space Flight Center, Lenkurt Electric Co., Inc., and Hughes Aircraft Company to provide detailed information exchanges regarding the design of the communication system and the tradeoffs which can be made between the parameters of the ground communication station equipment and those of the spacecraft.

Confirmation and agreement was obtained regarding the system computation techniques employed by Hughes, Lenkurt, and Goddard. The discussions confirmed the suitability of the transponder RF bandwidth of 25 mc. Subsequent computations by the participating organizations will use a ground transmitter power output of 2 kw for system computations pertaining to the FM frequency translation model of transponder operation. The computations for the multiple-access mode will continue to employ a ground transmitter peak power capability of 10 kw and an average power output of 1.5 kw.

The system carrier frequency assignments were revised as shown in Table 2-1.

The bandwidth of 25 mc available for each of the signals was not changed. Identical carrier frequencies are used in both modes of the transponder dual-mode transponder, but only a 5-mc bandwidth is needed for the ground-to-spacecraft link of the multiple-access mode. In addition to the above communication carriers, the spacecraft will radiate an unmodulated beacon at 4080 mc.

TABLE 2-1. CARRIER FREQUENCY ASSIGNMENTS (MEGACYCLES)

Transponder	Ground - Spacecraft		Spacecraft - Ground	
	From	To	From	To
1	6210	6212.1	3990	3992.1
2	6271	6271.4	4050	4051.4
3	6330	6330.7	4110	4110.7
4	6390	6390.0	4170	4170.0

The conclusion was reached that if each ground station equipment complement includes the capability for transmitting a crystal-controlled pilot tone, the requirement for a master control ground station may be reduced to that of only providing channel assignment and tabulation of channel usage.

The system frequency stability requirements were discussed and all equipment allocations were nearly resolved. The system short-term stability requirement is 6 cps, terminal to terminal, and the long-term stability requirement is 2 cps, terminal to terminal.

The spacecraft allocations, or permissible contributions, are 4 cps, rms, over a measured interval to be further defined (but in the area of 300 milliseconds) and a long-term stability of one part in 10^7 for 24-hour periods. Final resolution of the stability allocations will be completed during further Hughes-Lenkurt coordination.

The system design of the multiple-access mode will use spacecraft transponder single sideband to phase modulation conversion of test tones at a modulation index of 0.25.

INTERFACES

Telemetry, Tracking, and Command

On 8 October 1962, a conference was held at Goddard to discuss the Advanced Syncom telemetry and command requirements and to determine the best approach to meeting the requirement with one of the Goddard telemetry and command standard systems.

Preliminary studies indicate that a PFM telemetry system and an OGO-type command system will satisfy the Syncom II requirement while maintaining compatibility with NASA ground equipment.

Revision of the preliminary design discussion contained in the 15 August 1962 Initial Project Development Plan is in process and will be finalized after further coordination with Goddard.

Launch Vehicle Interface

The phased-array transmitter antenna stack has been shortened and results in a reduction of the antenna protrusion beyond the interstage structure that attaches to the Agena D. A 2-foot-diameter recess is provided in the top of the Agena vehicle to clear the antenna (Figure 2-1). The receiving antenna now extends 2.5 inches into this recess.

SYSTEM RELIABILITY

The system reliability studies have been directed toward two major tasks during this reporting period: 1) spacecraft subsystem design analyses, and 2) special system reliability analyses. The Advanced Syncom reliability assurance program was further defined.

Design Analyses

The general upgrading of the spacecraft reliability estimate presented in the September Monthly Progress Report, based upon an accurate parts count and application study for each subsystem as the designs mature, is in process. Specific emphasis has been placed upon incorporating accurate component data for the transmitting antenna control electronics into the reliability computer program to determine the effect upon spacecraft reliability. The reliability estimates for this unit presented in previous reports have been based upon reliability objectives rather than estimates. Since the controller employs digital computer techniques, further analysis of acceptable failure rate data incorporating the selectivity and high derating characteristics of the components is being performed. This effort will be completed during the November reporting period and the resulting reestimated unit and system reliability levels will be reported.

In addition, several possible solar-electric panel configurations which incorporate n-p rather than p-n solar cells are being examined. Recommendations for a new power supply configuration based upon power requirements, reliability, and cost will be made. Failure modes will be determined along with the number of acceptable solar panel string failures such that the design will ensure that adequate power will be available to the subsystems during the lifetime of the spacecraft communications. Previous estimates have been based upon extrapolations of the Syncom I p-n array development. The development of an improved power supply mathematical model will permit a more accurate estimate of the power supply reliability function.

The launch sequence analysis discussed in the September Monthly Progress Report has been programmed, data acquired, and evaluation of

the results initiated. The probability of the spacecraft surviving launch and, having survived launch, the probability of surviving the orbital period will be presented in subsequent reports.

System Analyses

An evaluation of the general reliability function, $R(t)$, has been initiated to determine mathematical models for the following system parameters: launch rate to establish the initial system; deployment time; replacement criteria; time availability for a single spacecraft; and time availability for a three-satellite synchronous equatorial system. Briefly, the launch rate criteria will be defined by the rate of growth of the system complex and the number of spacecraft (channels) which become inoperative during the deployment period. The deployment time required to initiate a system may be readily determined from this function and a knowledge of the number of spacecraft launched. Replacement criteria will be derived in accordance with two basic assumptions: 1) there is a minimum number of channels per spacecraft acceptable to complete a successful mission, and 2) there is a mathematical model which accurately represents the system reliability function, $R_s(t)$. The time availability or up-time ratio is simply the percentage of time in a continuum of operating time that it is expected the spacecraft or system will be in an operable state. Thus, the mathematical definition of these relationships incorporating the spacecraft reliability function is expected to yield an accurate estimate of optimum parameters which are too vital to maximum communications for a minimum cost.

Reliability Assurance

Definitions of the reliability assurance tasks including further evaluation of Syncom I parts failure information, and the subsystem reliability program plan for the Syncom II flight hardware program were expanded.

Syncom I failure data which are available on both a "failure card" basis and a "running time" log sheet are receiving additional evaluation. Additional data accumulated from other Hughes space programs are also being reviewed for possible application to Syncom II. Information from these sources, particularly as regards items experiencing multiple failures which are under consideration for application in Syncom II, were prepared for use by the designers and project management in improving the Syncom II designs.

Parts specifications are currently being reviewed to ensure adequacy of reliability, quality control, and testing requirements.

Requests for subcontractor bids on the hot gas reaction jet system prepared and distributed during October include the following items pertaining to reliability:

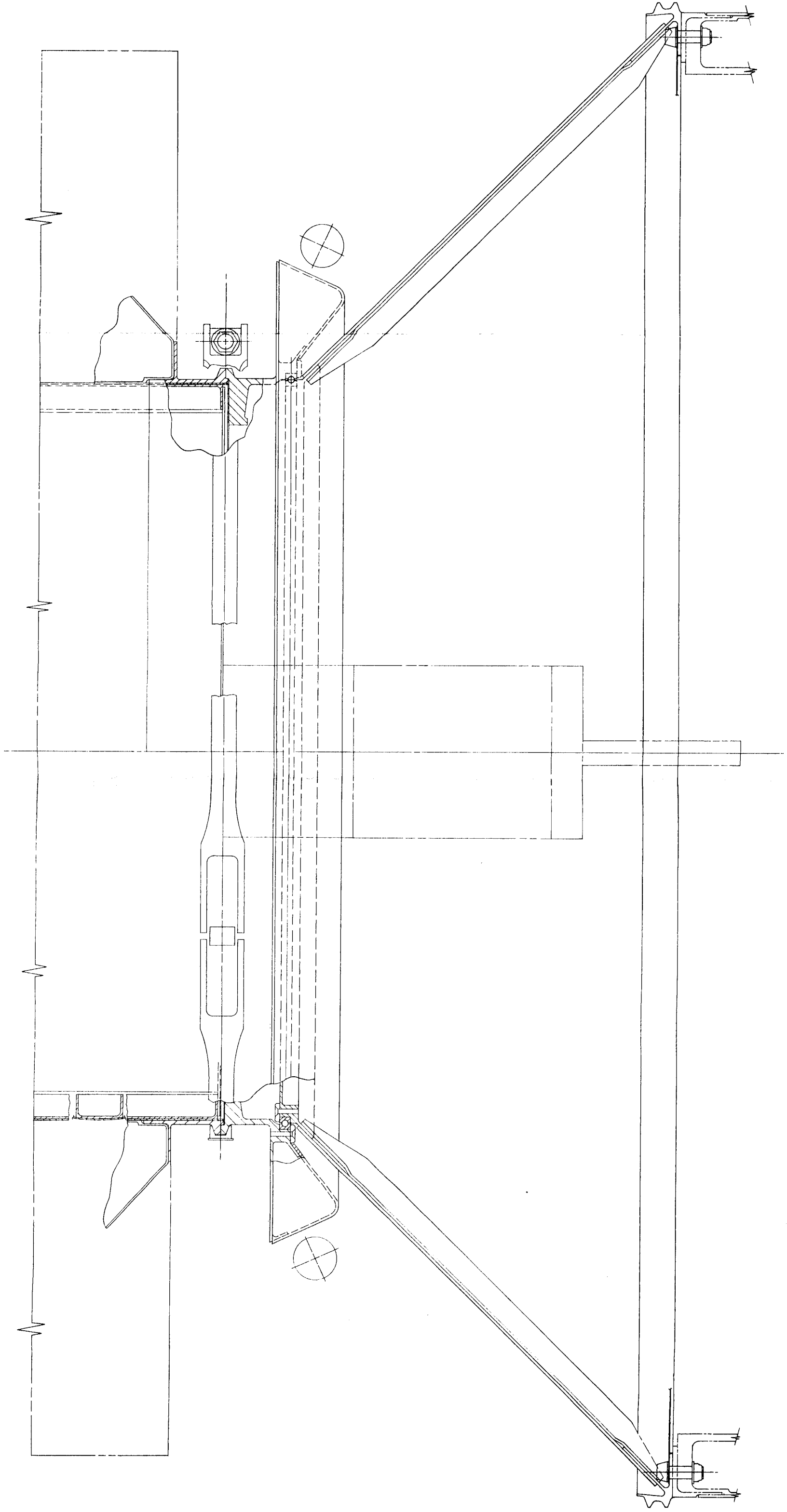


Figure 2-1. Proposed Interface, Syncom Mark II - Agena D

- 1) A complete reliability analysis of the proposed design, conducted to illustrate compliance with the reliability objective stated in the equipment specifications.
- 2) A formal reliability program plan including milestones for scheduled and documented design reviews and engineering analysis of significant test programs.
- 3) Submittal of procedures and methods for conducting design reviews with provisions for Hughes participation.
- 4) A thorough failure reporting and corrective action feedback system.

The current reliability assurance effort can be summarized as follows:

Evaluation of Syncom I Experience

- 1) Isolate high-failure-rate items and review their circuit applications.
- 2) Make recommendations to correct reliability deficiencies revealed by evaluation of Syncom I.
- 3) Conduct other studies as required.

Reliability Control (IPDP)

- 1) Interpret reliability objectives and establish test requirements for each design area.
- 2) Review reliability estimates for units or proposed design and compare with reliability requirements to establish design adequacy.
- 3) Propose alternate circuit configurations for possible reliability improvement.
- 4) Extend Syncom I parts control program as applicable.
- 5) Review and approve part specifications.
- 6) Isolate critical components for which special reliability effort will be required.
- 7) Establish critical component test plan.

Subcontractor Requirements and Evaluation

- 1) Establish reliability program requirements subject to project approval.
- 2) Participate in proposed evaluation.
- 3) Participate in surveys.

Prepare Reliability Assurance Followon Program

- 1) Contribute to the Syncom II reliability program plan for the follow-on phase.
- 2) Establish Syncom II data acquisition requirements.
- 3) Tailor existing Syncom I failure reporting and feedback system to Syncom II program. Revise reporting forms and procedures as necessary.
- 4) Prepare design review documents in accordance with established procedures.
- 5) Extend initial Syncom II parts control programs.

COMPONENTS AND MATERIALS

A tabulation of parts currently recommended for Syncom II circuit applications has been prepared to aid designers in selecting the preferred types of parts. The listing provides a cross-index which correlates Hughes parts identifications and specifications with equivalent vendor parts identifications. The tabulation greatly reduces the requirement for detailed reviews of parts specifications and encourages a reduction in the total number of different parts employed.

Syncom I drawings are being examined to define parts, materials, or processes considered acceptable for Syncom I but not preferred for Syncom II.

Syncom II environmental conditions have been studied to provide bases for subsequent determinations of long-term behavior of parts and materials which are critical to spacecraft reliability.

3. ADVANCED TECHNOLOGY DEVELOPMENT

DUAL-MODE TRANSPONDER

Phase Modulator

Assembly of a unit configuration breadboard phase modulator was completed with the exception of fabrication and installation of the hybrid transformer. The phase modulator is employed in the multiple-access transponder to convert, without demodulation, the received band of single-sideband signals to a low deviation phase-modulated signal at 32.5 mc. The 32.5-mc signal is subsequently multiplied up in frequency to produce a wide-deviation phase-modulated 4-kmc signal which is amplified for transmission by the traveling-wave tube.

2119-mc Isolator

The 2119-mc isolator has been sealed from the three-port circulator used as an isolator in Syncom I. The 2119-mc isolator is used in the local oscillator channel of the multiple-access transponder. Figure 3-1 shows the interior configuration of the circulator. The top port is terminated with a load to absorb reflected energy.

Output RF Power Switch

The output RF power switch selects one of two redundant traveling-wave tubes in the transponder and connects it to the output multiplexer.

A three-port circulator is being adapted to this application by controlling the direction of magnetic field and hence the direction of circulation. Figure 3-2 shows the relay. A current is applied to the coil which sets up a magnetic field in the garnet inside the circulator. The external current can then be removed. Figure 3-3 shows the relay being tested. The total loss due to mismatch and insertion loss is expected to be less than 0.2 db.

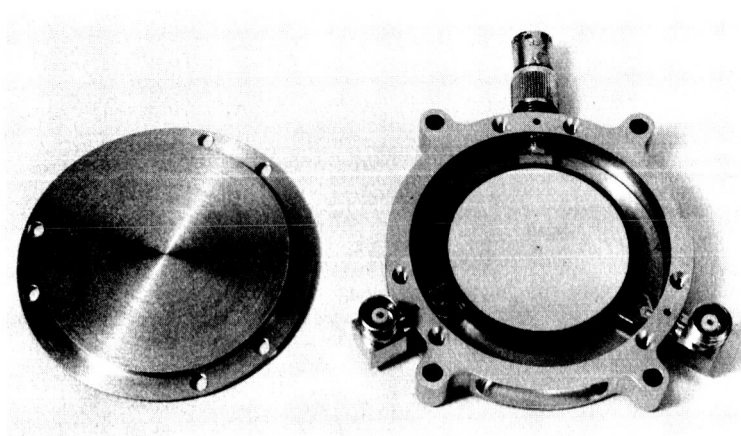


Figure 3-1. 2119.4-mc Isolator
Modified from Mark I for Mark II

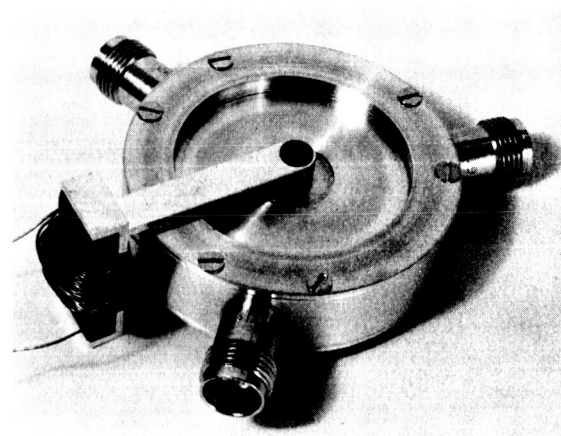


Figure 3-2. Newly Designed RF
Coaxial Power Relay for Mark II
Antenna Configuration for
Selection of Redundant
Traveling-Wave Tube

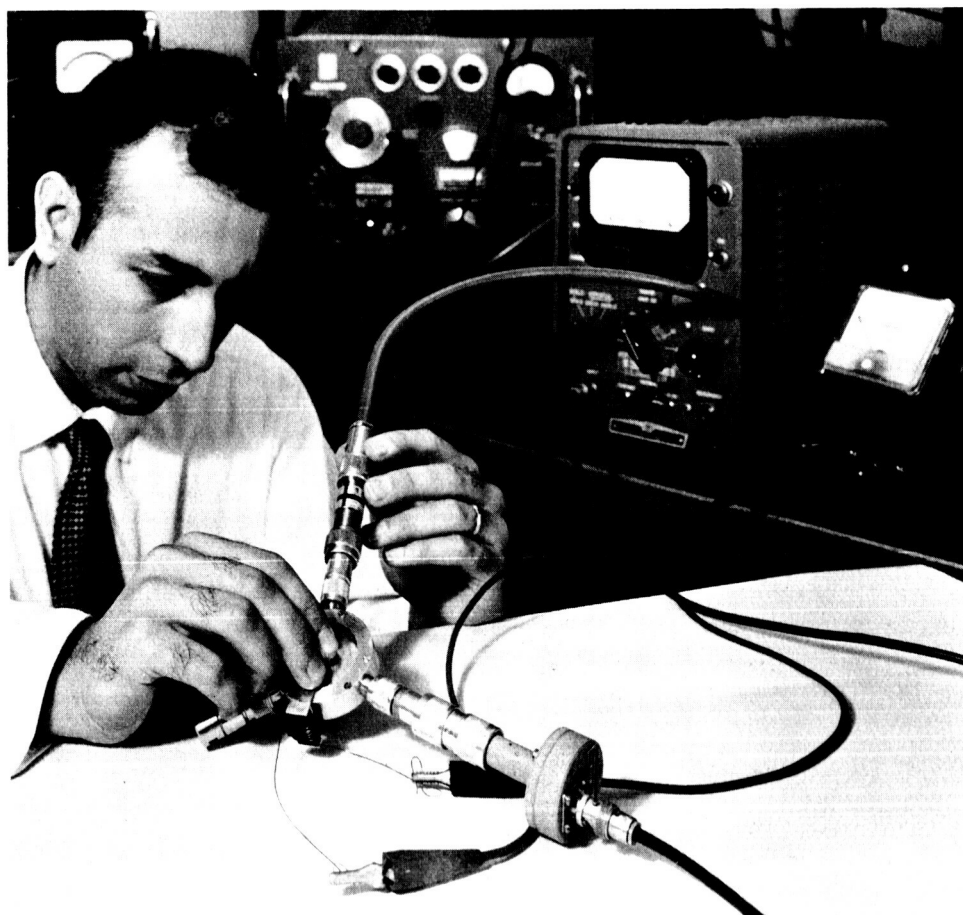


Figure 3-3. RF Coaxial Power Switch Being Tested

TRAVELING-WAVE TUBE

(Figures 3-4, 3-5, and 3-6)

During this period, three developmental 384H tubes were assembled to the prepackaging stage. Of the three, No. 384H-1 was tested; due to an assembly error, No. 384H-2 was discarded; and No. 384H-3 will be tested during the initial portion of the next report period.

Results of tests conducted on No. 384H-1 were quite satisfactory as experimental data were close to predicted values. Hence, only minor engineering modifications should be necessary to obtain final parameters. The tube exhibited excellent collector depression and the efficiency was over 31 percent. The tube was stable under short-circuit conditions. Also, beam focusing and perveance observed during the tests indicated that the new electron gun was properly designed. Power output and beam voltage at the desired frequency, 4.0 gc, were slightly low. A minor change in the helix pitch should move the optimum performance frequency closer to 4.0 gc and sufficiently raise the beam voltage to obtain the desired developmental tube power output of 2.5 watts.

The magnetic focusing field provided by the platinum cobalt magnets was found to be greater than the required value and investigation is currently under way to determine the possibility of using Alnico VIII magnets in place of the expensive platinum cobalt magnets. If this can be achieved, it will lower the production cost of the tubes.

A modification of the magnet stack on tube No. 384H-1 was initiated. However, during this operation an open condition in the RF coupler developed and the tube is now awaiting repair.

Preassembly work has commenced on several tubes which will have the new helix pitch. It is expected that several of these tubes will be assembled to the prepackaging stage, tested, and possibly packaged during November.

PHASED-ARRAY TRANSMITTING ANTENNA

Array Development, Horizontal Polarization

The cloverleaf antenna design was modified to increase the coupling and improve the pattern. The first parts, manufactured with closer tolerances than those previously measured, are being assembled.

Array Development, Vertical Polarization

The breadboard 16-element vertically polarized array at 4 kmc was completely assembled except for the fiberglass sleeves. The individual elements were matched by means of a quarter-wave matching section located just below the lowest gap. The resultant bandwidth was adequate for the initial tests.

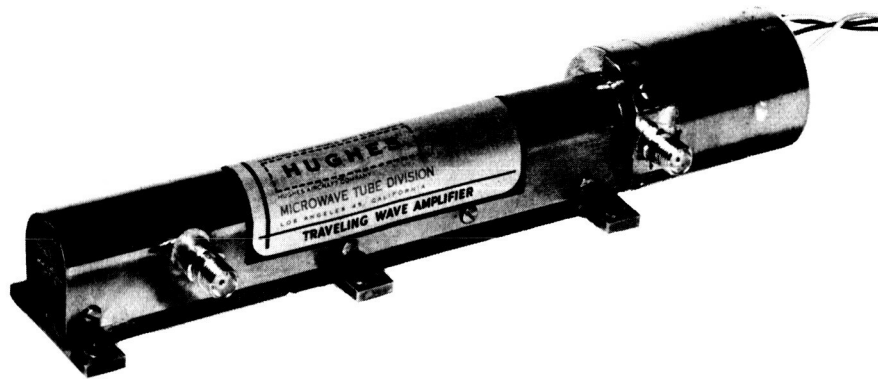


Figure 3-4. Assembled 314H Traveling-Wave Tube for Syncom Mark I
(The 384H for Syncom Mark II will be identical in exterior appearance to the 314H)

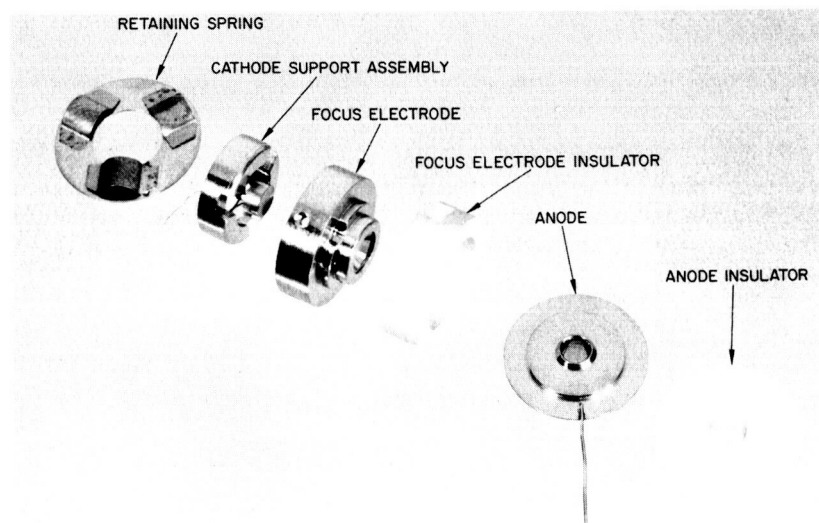


Figure 3-5. Electron Gun Components

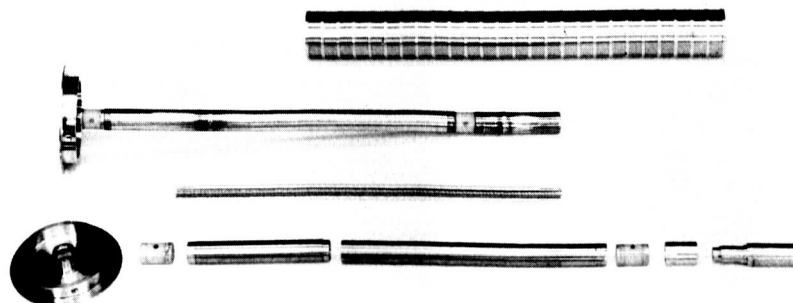


Figure 3-6. Syncom Traveling-Wave Tube Helix Assembly
(Component parts, assembled helix, and stack of platinum cobalt magnets that encircle helix when tube is assembled)

A test jig was constructed using a 3-db power splitter, two eight-way power splitters, and coaxial cables cut to specific lengths to provide element excitation in the proper phasing, connected to the antenna. Figure 3-7 shows the antenna in the test fixture, while Figure 3-8 shows the equipment used in making the pattern measurements. A plot of the pattern measured with this setup is shown in Figure 3-9 along with the computed pattern.

RF Circuits

Ferrites

A number of test fixtures have been fabricated to facilitate matching of transitions from a rectangular waveguide to the circular waveguide used in the phase shifter. With the aid of these fixtures, a matching section has been made to match the ferrite to the Stycast K3 dielectric that fills the remainder of the circular waveguide. A good match has been obtained over the band. Delivery of the remaining ferrites has been delayed because of a fire at the vendor's facility. Delivery of adequate ferrite cylinders to permit assembly of the array and phase shifters during November has been promised.

Input Couplers

The input couplers have been completed and tested. Figure 3-10 shows one of the couplers. The input connector is a type TNC. An adjustable probe and short opposite the input probe is used for matching. The measured input VSWR over a 5 percent band was less than 1.1, measured through a type N to TNC tapered transition. A thin resistor, made of Filohm Mica (50 ohms/square) is located in the coupler at 90 degrees to the input probe, to absorb any reflected power that is cross-polarized. The VSWR into the circular waveguide for this polarization was less than 1.1 over most of the band, rising to 1.3 at one end. The dielectric material in the guide is Stycast K3.

Field Coils

A shipment of eight of the phase shifter field coils has been received from the manufacturer, Skorka-Langdon.

Power Divider

The ground planes and strip-line for the eight-way RF power divider have been received and are being assembled. Figure 3-11 shows the photoetched strip-line circuit, consisting of seven hybrid rings. The input is at the right side, with the eight outputs located symmetrically around the circumference. The unused arms of the hybrids will be terminated at the ground plane. Figure 3-12 shows the two ground planes assembled. Type TNC connectors will be used, to match the input couplers described above.

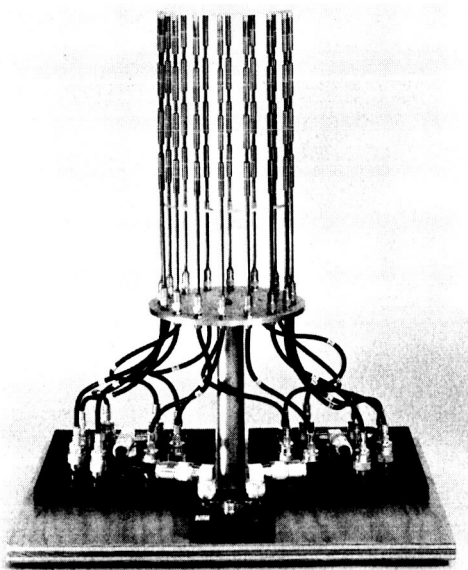


Figure 3-7. 4-kmc Phased-Array Antenna in Test Fixture for Measuring Static Beam Patterns

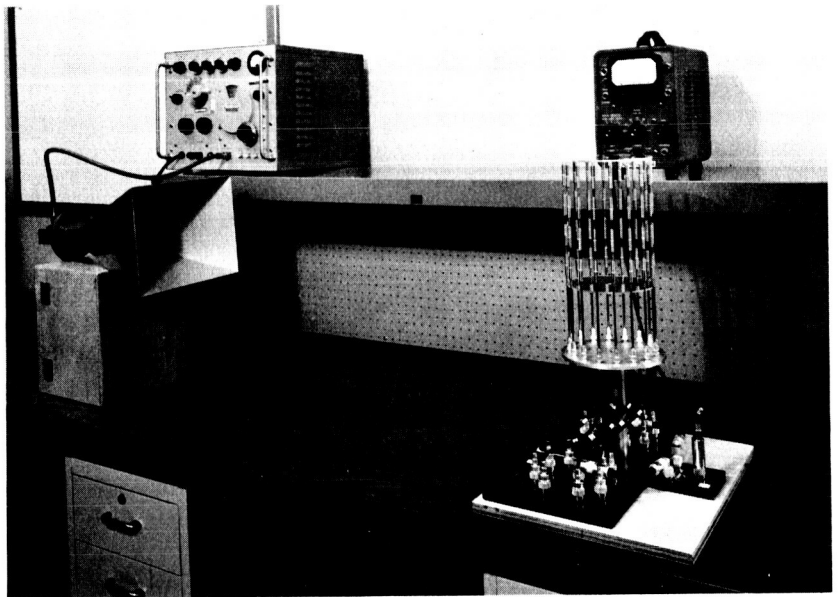


Figure 3-8. Test Setup for Measuring Static Beam Pattern of 4-kmc Phased-Array Antenna

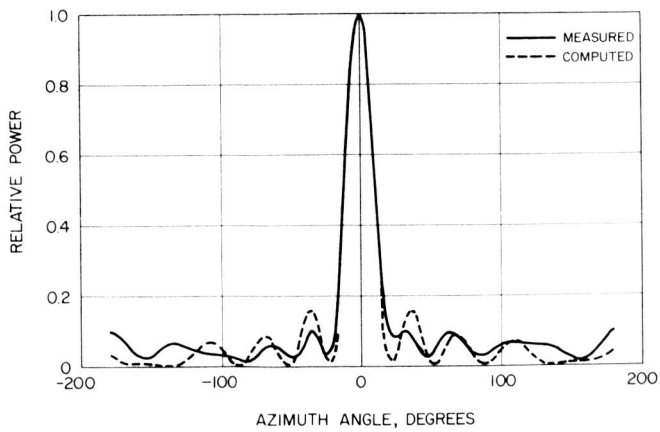


Figure 3-9. 4-kmc Phased-Array Antenna Pattern

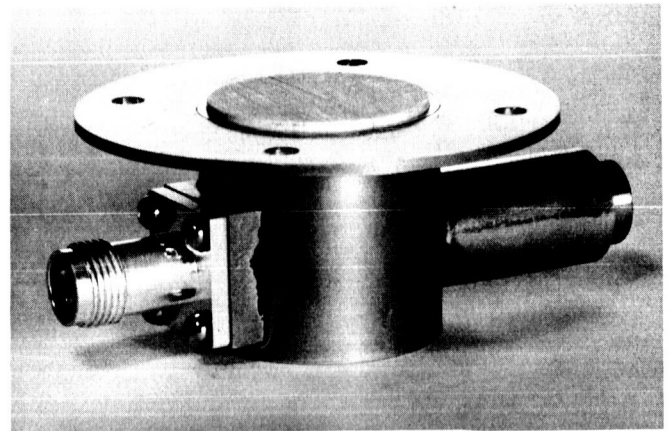


Figure 3-10. Ferrite Phase Shifter Input Coupler

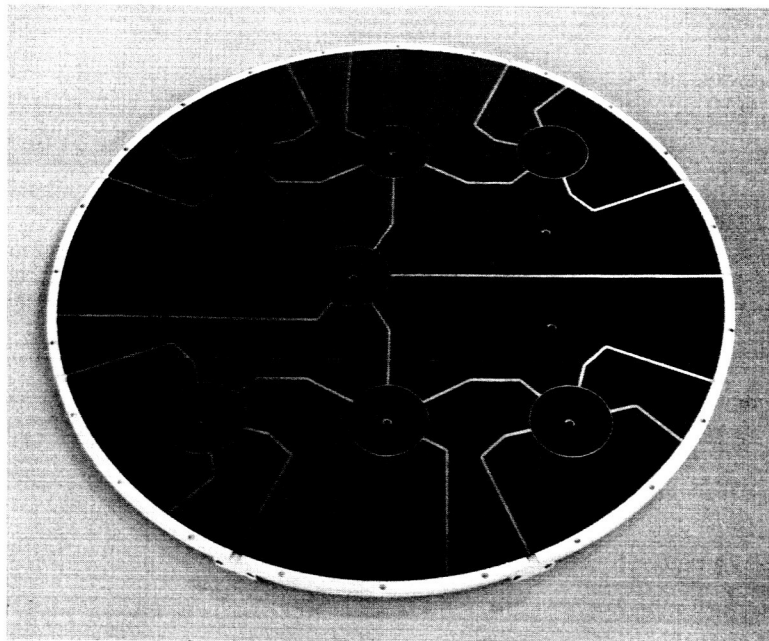


Figure 3-11. Stripline Photoetched Circuit
Pattern of Phased-Array Antenna
Power Divider

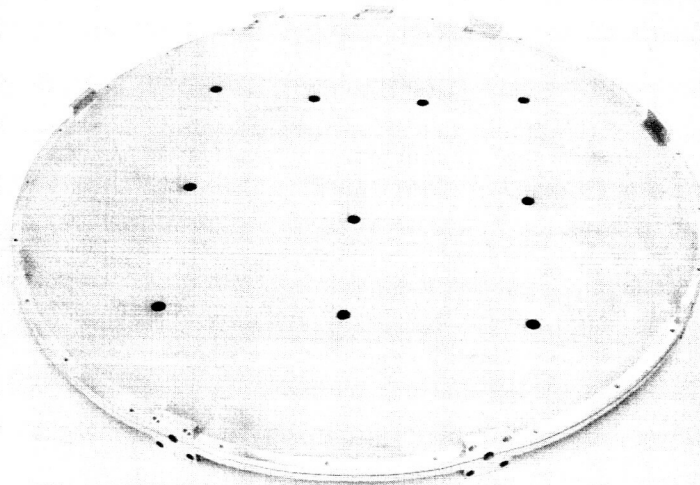


Figure 3-12. Stripline Power Divider for Phased-
Array Antenna System, Complete Unit

All-Strip-Line Circuit

Work has begun on an all-strip-line version of the antenna RF system, replacing all coaxial cables and connectors. The major areas under study are the waveguide probe to strip-line transition, and vertical transitions from one strip-line circuit to one above or below it.

Control Electronics

Analog Electronics

A new circuit approach to the waveform-generating circuits which occur after the signal splitter has resulted in a considerable reduction in complexity and in improved reliability. The basic waveforms which must be generated to drive each of the eight ferrite phase shifters are of the forms

$$\cos \psi_{\max} \cos [(\omega t + \theta) + \eta (22.5 \text{ degrees})]$$

$$\sin \psi_{\max} \cos [(\omega t + \theta) + \eta (22.5 \text{ degrees})]$$

where ω is the spin rate of the satellite, ψ_{\max} is 2π , θ is the angle between the sun-spacecraft and spacecraft-earth lines, and η depends on the particular phase shifter. The digital control circuits have $(\omega t + \theta)$ stored in a digital register. This is first converted to a triangular wave by a binary voltage weighter and then shaped by a diode shaping network to produce $E(t) = E_0 \cos (\omega t + \theta)$. The new circuits are an extension of this technique, consisting of a diode-controlled amplifier which has an input-output voltage transfer with a triangular waveform shape, followed by a diode shaping network. The resultant output is of the form $\cos [E(t)]$ and hence of the form $\cos [E_0 \cos (\omega t + \theta)]$. The sine term is generated similarly.

The final power amplifier design has been completed.

Digital Control Electronics

The block diagram and logic equations for the spacecraft timing reference and control signal generating circuitry have been finalized and completed. Final circuit design was 90 percent complete at the end of the report period. About 45 flat cards of 25 types will be necessary to package the digital electronics. Twenty of these 25 types are in first draft, or further completed; the remainder are in design phase. Preliminary product design of the cards will be completed before mid-November.

All long lead time components were ordered and fabrication of the engineering model will be initiated in the early part of the next report period. Chassis wiring design of a card tester is 80 percent complete.

The digital control electronics circuits are listed below:

- 1) Standard flip-flop
- 2) Standard inverter
- 3) Amplifier
- 4) Standard AND gates
- 5) Tuning-fork oscillator
- 6) Fork output amplifier
- 7) Low-frequency clock flip-flop
- 8) Exclusive Nor
- 9) Standard one-shot
- 10) Multiple-set gate
- 11) Initial conditions gate
- 12) Add/subtract amplifier
- 13) Interstage gate backward/forward counter
- 14) Amplifier-pulse shaper
- 15) Backward/forward counter flip-flop
- 16) Slow voltage turn-on
- 17) Antinoise bias buffer
- 18) Frequency counter reset gate
- 19) Sine wave inverter
- 20) Backward/forward wave switches
- 21) Diode function generator
- 22) Sine wave ladder
- 23) Phase lock loop ladder
- 24) Sine/cosine wave amplifier

- 25) Voltage-controlled oscillator
- 26) Auxiliary power supply -8, +8 volts
- 27) Auxiliary power supplies -3, +1, +13.4 volts
- 28) Auxiliary power supplies -8, +8 volts
- 29) Auxiliary power supply +23 volts
- 30) Auxiliary power supply +6, +5, -6 volts
- 31) Function A gate

COLINEAR-ARRAY RECEIVING ANTENNA

Gain and pattern calculations were completed for a tapered distribution four-element linear array with a one-wavelength interelement spacing. Also, calculations were made for 0.9λ spacing. The best compromise between beam width and gain appears to be 0.9λ spacing. Results for this spacing are shown in Figure 3-13. With a 0.45, 1.0, 1.0, 0.45 taper, a beam width of 17.4 degrees is realizable with a gain of almost 8.0 db.

One method of improving the impedance broad-banding problem is to overcouple the elements. However, calculations have shown that for uniform distribution and one-wavelength spacing, beam shift as a function of frequency is worse for overcoupled elements than for the case of elements coupled to give a matched input. These results are based on the assumption that the element impedance has not changed with frequency. The validity of this assumption will be checked when impedance measurements on various element configurations are made. For an overcoupling ratio of 2:1 in power, the beam shift was approximately 1 degree, twice that of the matched case.

Preliminary calculations on the above tapered distribution have shown that for a 2-percent frequency change, the beam width changes by only 0.2 degree and the gain drops by less than 0.1 db. These numbers are based on properly coupled elements and on a nonchanging element impedance.

Since the tapered illumination for the uniformly spaced array mentioned above satisfies the system requirements, the nonuniformly spaced approach will not be pursued.

A fixture for obtaining pattern and impedance data on the radiating element has been designed and is now being fabricated. By adjusting the parameters of the elements, the proper series resistance will be obtained to satisfy the requirements of the tapered illumination mentioned above.

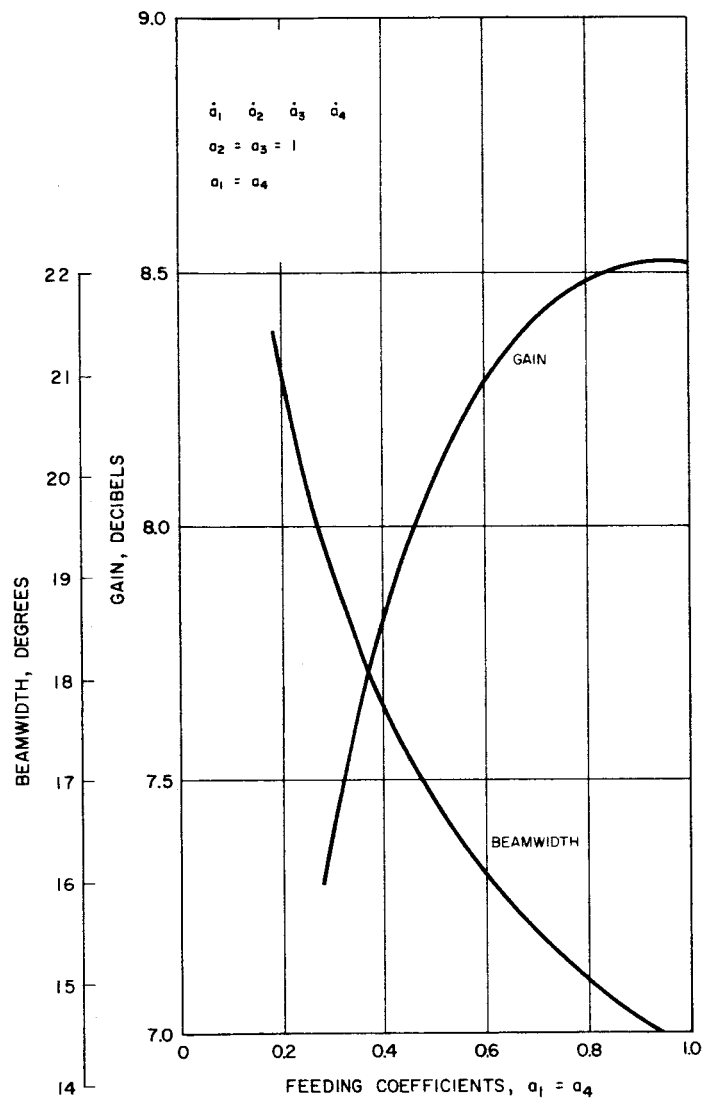


Figure 3-13. Gain and Beam Width versus Amplitude of Outer Element Feeding Coefficients for 0.9λ Element Spacing

STRUCTURE

Structural Design and Analysis

Material investigations have been completed on the major sub-assemblies of the structure. Aluminum and magnesium castings and aluminum and magnesium built-up sections were evaluated for the thrust tube design. The built-up aluminum section was selected because it is approximately 5.5 pounds lighter and is stiffer than the other sections. The selected configuration is made up of two machined rings (forward and aft), an aluminum sheetmetal tube, and 12 machined stiffeners.

Aluminum and magnesium plates were investigated for the bulkhead stiffener ribs. Since a minimum practical machining thickness is adequate for either material, magnesium was selected because of the weight advantage.

The trusses supporting the sun sensors and control jets will be made of aluminum tubing because its stiffness per pound is greater than magnesium. The design of the forward subassembly (tubular trusswork) is now firm, and bath detail and assembly drawings have been initiated.

The material selection of other structural components will probably have little effect on the overall stiffness of the vehicle. It is estimated that the structural weight will be approximately 125 pounds or nearly 10 percent of the planned total weight injected by the Atlas-Agena. However, an additional 250 pounds of injected weight can be accommodated with little or no increase in structural weight.

Axially symmetrical vibration studies of pressurized shells, which include fuel tanks in addition to the apogee motor, are nearly completed. An apogee motor frequency requirement and recommended qualification test vibration levels were included in the apogee motor specifications.

A technical conference was conducted at General Dynamics - Convair, San Diego, to determine the applicability of their vibration analysis digital computer program to Syncom-type structures. The program appears capable of adequately representing the spacecraft in a vibration analysis. A portion of the program manuals have been received and are being reviewed by dynamics personnel.

The detail drawings of the long lead time items are essentially completed and ready for release to fabrication. Drawings of the aft and center subassemblies have been completed and are now being checked prior to release.

Design Integration

General Arrangement

The spacecraft structure separates into three subassemblies: forward, center, and aft.

The aft subassembly (Figure 3-14) is composed of a 30-inch-diameter fabricated central thrust tube, with a V-clamp separation flange at the aft end, and a flange for mounting the 30-inch-diameter spherical apogee motor at the forward end. A bulkhead at the apogee motor flange is supported by 12 radial ribs attached to the periphery of the thrust tube. These ribs carry the load of the eight bipropellant control system fuel and oxidizer tanks, and the four electronic quadrant packages.

The eight traveling-wave tubes (and their associated power supplies) and the four paired telemetry transmitters are attached to the faces of these radial ribs. The antenna electronics package, composed of a flat cylindrical housing (containing the ferrite phase shifters, power splitter, multiplexers, receiver mixers and preamplifiers, and supporting the transmitter antenna array and the receiver antenna) is suspended within the aft end of the thrust tube. It is attached to the ends of the stringers inside the thrust tube.

Joining the aft structural subassembly to the forward subassembly are 12 flanged flat panel members, to which the eight pressure tanks are attached in pairs for installation into the structure. A thin sheetmetal cylinder is attached inboard to the forward and aft bulkheads and to the 12 tank panels.

A segmented metal cylinder is attached outboard in the same manner as the inner cylinder. Four of the segments over the fuel and oxidizer tanks are permanently attached to form four double torque-boxes to provide torsional rigidity. The other four segments over the electronic packages are removable to provide access to the electronics packages. The two nutation dampers, the two velocity control rockets, and the storage batteries are attached to the tank panels.

The forward structure consists of a tubular trusswork frame attached to the forward bulkhead. This structure comprises eight A-frame trusses with their bases attached, through the bulkhead, to the tank panels.

Two jets that can be swiveled combine the functions of spin-speed control, attitude control, and orbital inclination control. The jets are supported by two opposite trusses, which also carry two of the four V-beam sun sensors. Two other trusses support the other two sun sensors. The four whip antennas are mounted on the intermediate trusses. Pods are provided on the trusses to support the forward eight solar panels.

The cylindrical surface of the spacecraft consists of a plastic and aluminum honeycomb structure, 57 inches in diameter and 50 inches long, divided into 16 panels, and covered on the outside with silicon solar cell

modules. To eliminate the possibility of the solar panels carrying space-frame structural loads, each panel is mounted from a single center point with an integrally stiffened rigid structure of ribs radiating from the central mounting point.

The two ends of the spacecraft are closed by thermal radiation barriers. The barrier at the aft end has an additional function of acting as a ground plane for the transponder antenna. Additional thermal control is obtained by the use of variable emissivity devices which are attached to the ribs at the aft end of the spacecraft.

A full-scale wood and plastic mockup of the spacecraft is nearing completion (Figure 3-15).

Weight Summary

Current weight data for the solid-propellant configuration is summarized in Table 3-1. A detailed weight statement through final orbit condition is shown in Table 3-2.

Weight changes from those last reported have occurred as follows:

Power supply — Addition of solar panel stiffeners (3.5 pounds)

Miscellaneous — Increased allowable dynamic balance weight
required by 3.0 pounds

Structure — Increased weight allowed for electronic package
supports (1.1 pounds)

Weight of thrust tube increased due to calculation
error (7.0 pounds)

At present a review is being made to determine a final weight for the ribs (to which the thermal switches are attached). A redesign of the variable emissivity device is being considered as an alternate solution to a change of rib material from magnesium to aluminum. Further investigation will be conducted by thermal control analysts and design specialists.

THERMAL DESIGN

Effort is continuing on coordination with spacecraft design to ensure achievement of thermal control and to establish the requirements for testing thermal control surface coatings. Investigation is being made of semiactive temperature control devices.

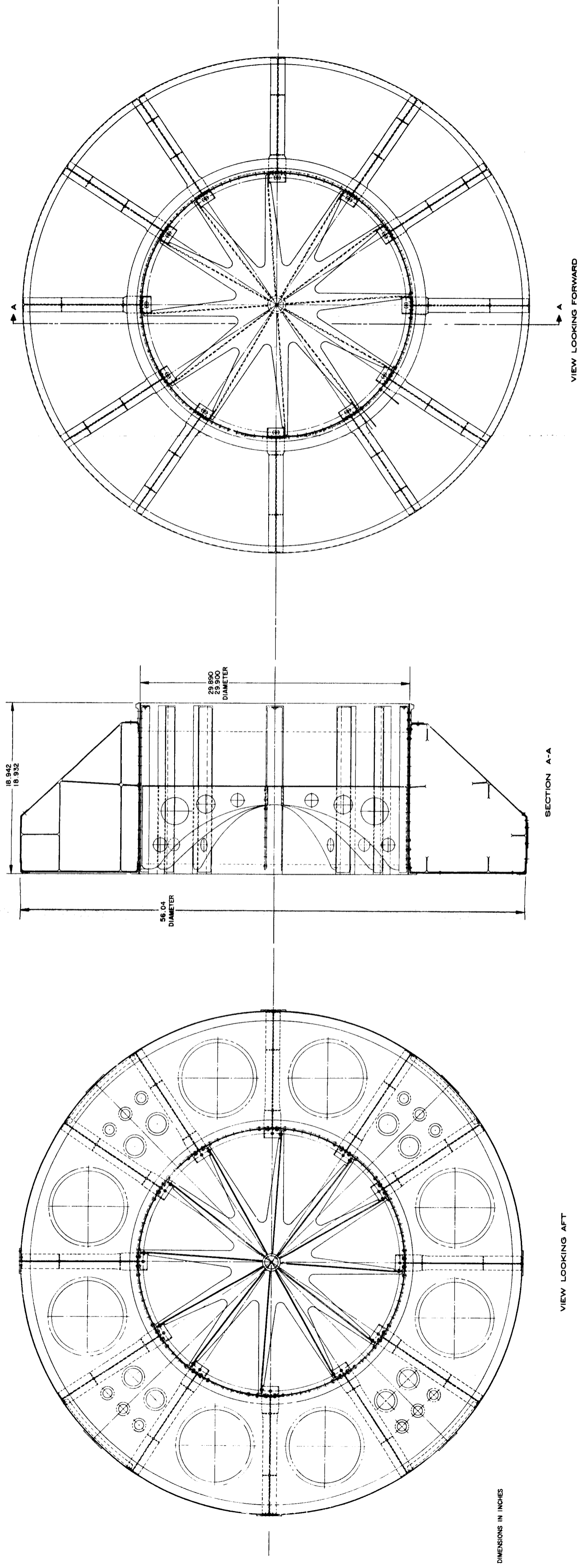
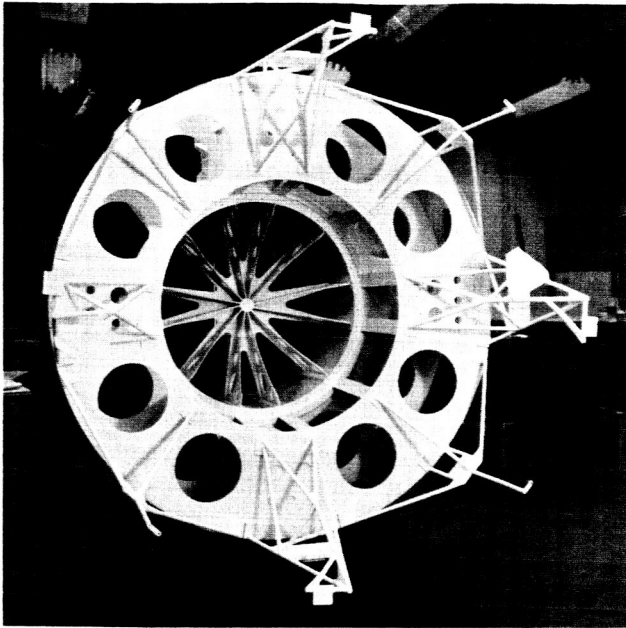
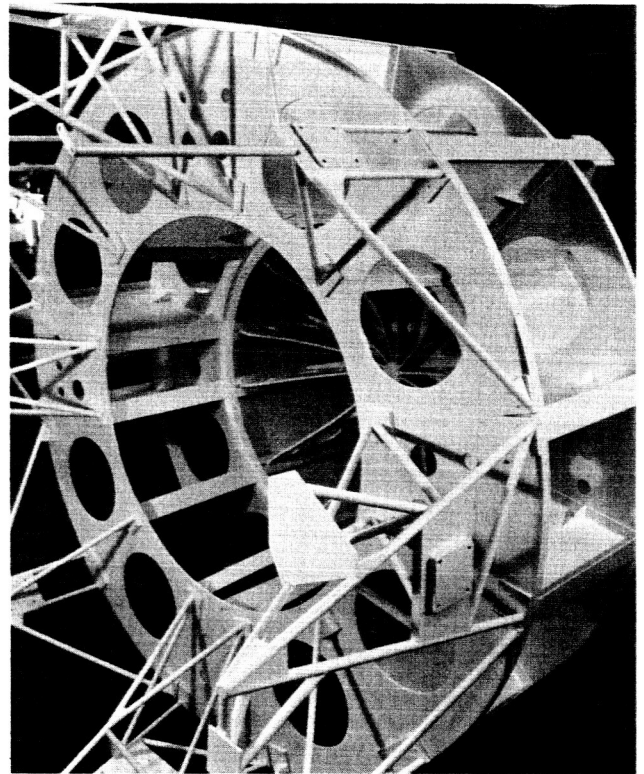


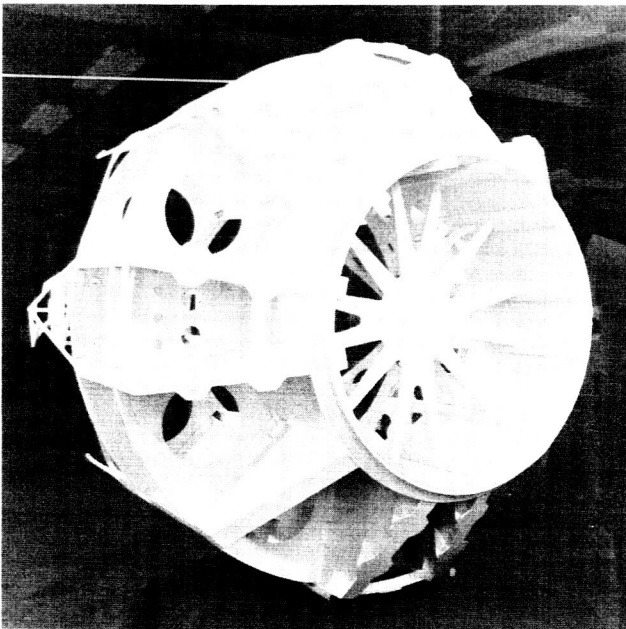
Figure 3-14. Aft Structure Subassembly



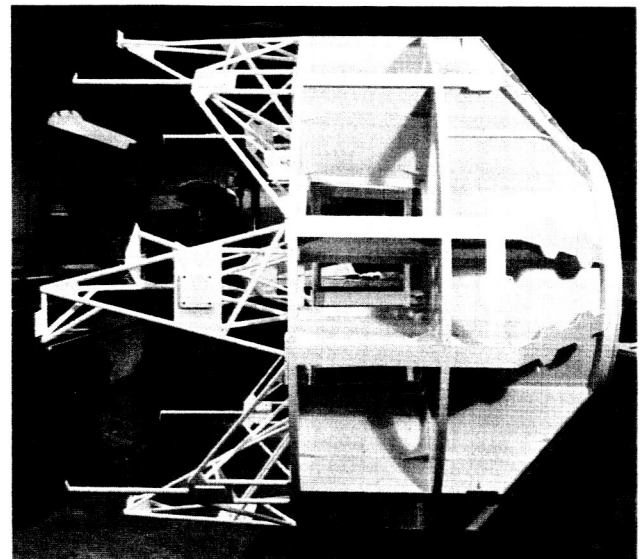
a) View Looking Aft



b) Forward Quarter View



c) View Looking Forward



d) Side View

Figure 3-15. Mockup Structure

TABLE 3-1. SYNCOM II ESTIMATED WEIGHT STATUS
Solid-Propellant Configuration

Subsystem	Δ Weight*	Weight, pounds		\emptyset **	
Electronics	+3.5	130.0		0.255	
Wire harness		19.9		0.039	
Power supply		102.6		0.202	
Controls		38.6		0.076	
Propulsion	+8.1	75.1		0.148	
Structure		123.6		0.243	
Miscellaneous	+3.0	19.1		0.037	
	Weight, pounds	Z-Z	I _{Z-Z}	I _{X-X}	R/P
Final Orbit Condition	(508.9)	23.5	45.3	36.5	1.24
N ₂ pressurization	3.2				
N ₂ H ₃ -CH ₃ fuel	55.6				
N ₂ O ₄ oxidizer	92.4				
Total at apogee burnout	(660.1)	23.5	62.4	45.1	1.39
Apogee motor propellant	622.5				
Total payload at separation	(1289.3)	24.5	74.6	57.4	1.30
<p>*ΔW = change in subsystem weight since last report. **\emptyset = ratio of subsystem weight to final orbit condition weight.</p>					

TABLE 3-2. SYNCOM II DETAIL WEIGHT STATEMENT
Solid-Propellant Configuration

Subsystem	Weight, pounds	Δ Weight, pounds
<u>Electronics Subsystem</u>		
Electronics quadrant, 1	20.00	
Electronics quadrant, 2	20.00	
Electronics quadrant, 3	20.00	
Electronics quadrant, 4	20.00	
Telemetry transmitter	1.00	
Telemetry transmitter	1.00	
Telemetry transmitter	1.00	
Telemetry transmitter	1.00	
Traveling-wave tube and converter	4.00	
Traveling-wave tube and converter	4.00	
Traveling-wave tube and converter	4.00	
Traveling-wave tube and converter	4.00	
<u>Antenna Assemblies</u>		
Antenna electronics and support	30.00	
<u>Wire harness</u>		
Wire harness	9.95	
Wire harness	9.95	
<u>Power supply</u>		
Stiffener solar panels	8.00	3.50
Solar panels	42.80	
Battery package 1	12.95	
Battery package 2	12.95	
Battery package 3	12.95	
Battery package 4	12.95	
<u>Control subsystem</u>		
Fuel and oxidizer tank	3.25	
Fuel and oxidizer tank	3.25	
Fuel and oxidizer tank	3.25	
Fuel and oxidizer tank	3.25	
Thrust chamber	1.80	
Thrust chamber	1.80	
Thrust chamber	1.30	
Thrust chamber	1.30	
Miscellaneous	2.80	
Miscellaneous	2.80	
Miscellaneous	2.80	
Miscellaneous	2.80	

TABLE 3-2 (continued)

Subsystem		Weight, pounds	Δ Weight, pounds
Control subsystem (cont)			
Fill and vent valve		0.60	
Fill and vent valve		0.60	
Lines and fittings		1.00	
Lines and fittings		1.00	
Spin control assembly		1.25	
Spin control assembly		1.25	
Spin control assembly		1.25	
Spin control assembly		1.25	
<u>Propulsion subsystem</u>			
Apogee motor installation		75.10	
<u>Structure subsystem</u>			
Inner ring	676	5.60	
Outer ring	677+684	8.00	-0.80
Panel mounting	679	24.00	
Support antenna electronics	682+683	1.20	
Panel attachment	685+688	1.30	
Stiffener thrust tube	686	4.80	
Aft ring	687	4.30	
Bulkhead aft	689	3.40	
Ribs	690	2.60	
Ribs	690	2.60	
Ribs	692	2.90	
Ribs	692	2.90	
Ribs	692	2.90	
Ribs	692	2.90	
Thrust tube	694	28.50	7.00
Bulkhead forward	712	3.80	
Support electronics package	714+715	2.20	1.10
Tee	713	3.00	
Truss assembly		9.50	
Battery support		3.30	
Hardware and miscellaneous		3.90	0.80
<u>Miscellaneous and balance subsystem</u>			
Paint		3.00	
Thermal switch		4.50	
Nutation damper		2.00	
Miscellaneous		4.60	
Dynamic balance		5.00	3.00

HANDLING WEIGHT AND BALANCING EQUIPMENT

Preliminary investigations leading to the establishment of handling procedures and equipment requirements are being conducted. Definite requirements for the following items have been established:

- 1) Assembly cart
- 2) Vehicle lift fixture
- 3) Motor lift fixture
- 4) Static test fixture
- 5) Dynamic test fixture
- 6) Motor support stand
- 7) Motor rollover equipment
- 8) Spin fixture

HOT GAS REACTION JET CONTROL SYSTEM

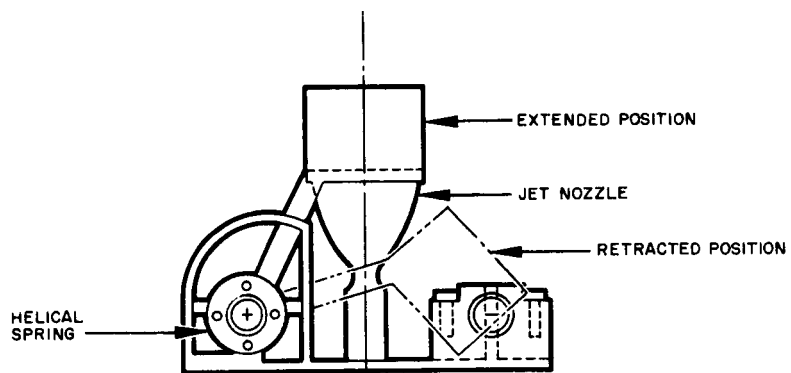
Performance Specifications

Performance specifications were completed and included in a request for proposal for a bipropellant rocket reaction control system. The request for proposal was issued to the following potential vendors: Aerojet-General Corporation; Bell Aerosystems Company; Walter Kidde Company; Marquadt Corporation; Minneapolis-Honeywell Regulator Company; Rocketdyne Division of North American Aviation, Inc.; Space Technology Laboratories Inc.; Tapco Division of Thompson-Ramo-Wooldridge, Inc.; Thiokol Chemical Corporation; Wright Aeronautical Division of Curtiss-Wright.

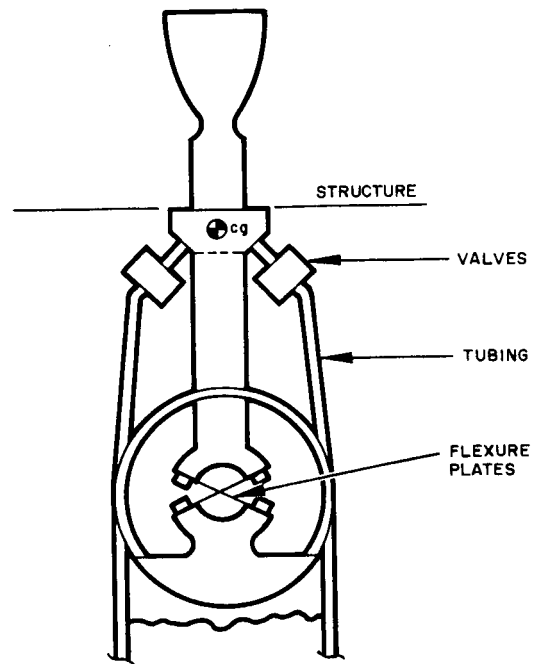
Proposals are to be submitted to Hughes for evaluation by 19 November 1962. A synopsis of the specification performance and physical requirements is included in Appendix A.

Spin-Speed Control Mechanism

The two spin-speed control mechanisms (Figure 3-16) discussed in the October report have received further examination. Vane thrust deflection feasibility studies are essentially complete; the rotating jet scheme is still undergoing evaluation.



a) Vane thrust deflection



b) Rotating jet

Figure 3-16. Two Spin-Speed Control Mechanisms

Analyses indicate that the vane spin-speed control device will be able to deflect the required amount of thrust with moderately sized vanes. Several tests will be required of the device: 1) testing of the mechanism on a centrifuge to verify mechanical characteristics; 2) thrust deflection verification testing; and 3) heat transfer tests. Care must be exercised with the thrust deflection measurements to ensure maintenance of proper space environment during test; the chamber must be large enough to ensure that reflections off the sides do not return to the vane, and pressures must be maintained below a designated value. Heat transfer from the vane to the crank must be restricted to prevent welding of the crank to the guide in which it travels. Figure 3-17 illustrates one method of achieving this. Conical sections are used to connect the vane and arm to provide a large radiating surface and small conduction surfaces for the heat.

The rotating jet mechanism is being analyzed to determine if a potential stability problem exists with the mechanism since there is no inherent damping involved. If the natural frequency of the mechanism is close to a multiple or submultiple of the spin speed, the inherent jet misalignment torque could excite a large amplitude oscillation of the jet by causing enforcement of the oscillation with each jet pulse. This would result in a loss of spin-speed control as well as the possibility of incurring damage to the jet by forceful contact against the ± 8 degrees travel stop.

There is no stability problem associated with the vane thrust deflection mechanism since it operates in "bang-bang" fashion. When the vane is in position next to the jet, the jet force acts on the vane at right angles to its direction of travel. Vibrations of the jet are absorbed by a guide in which the vane travels.

One method of ideally avoiding this oscillation buildup with the rotating jet is to tune the response of the mechanism in such a way that each disturbance torque causes an oscillation in a reverse phase to the previous disturbance oscillation, thus causing exact cancellation of the oscillation every second jet pulse. This optimum relationship between the nominal spin rate period, T_s , and the desired period of the mechanism, T_m , is

$$\frac{T_m}{T_s} = \frac{1}{n + \frac{1}{2}}$$

where n is any integer 0, 1, 2, A reasonable size for the mechanism restricts n to about 3. Thus, for a nominal spin rate period of 0.6 second the period of the mechanism is 0.171 second or a natural frequency of 5.83 cps. A change in n to 2.5 or 3.5 would cause phase reenforcement of the oscillation and instability of the mechanism. This corresponds to a change in the frequency ratio of only 14 percent. Investigation of tolerances in machining the propellant tubing (which comprises the restraining spring for the mechanism) and deviation in the spin rate from nominal (caused

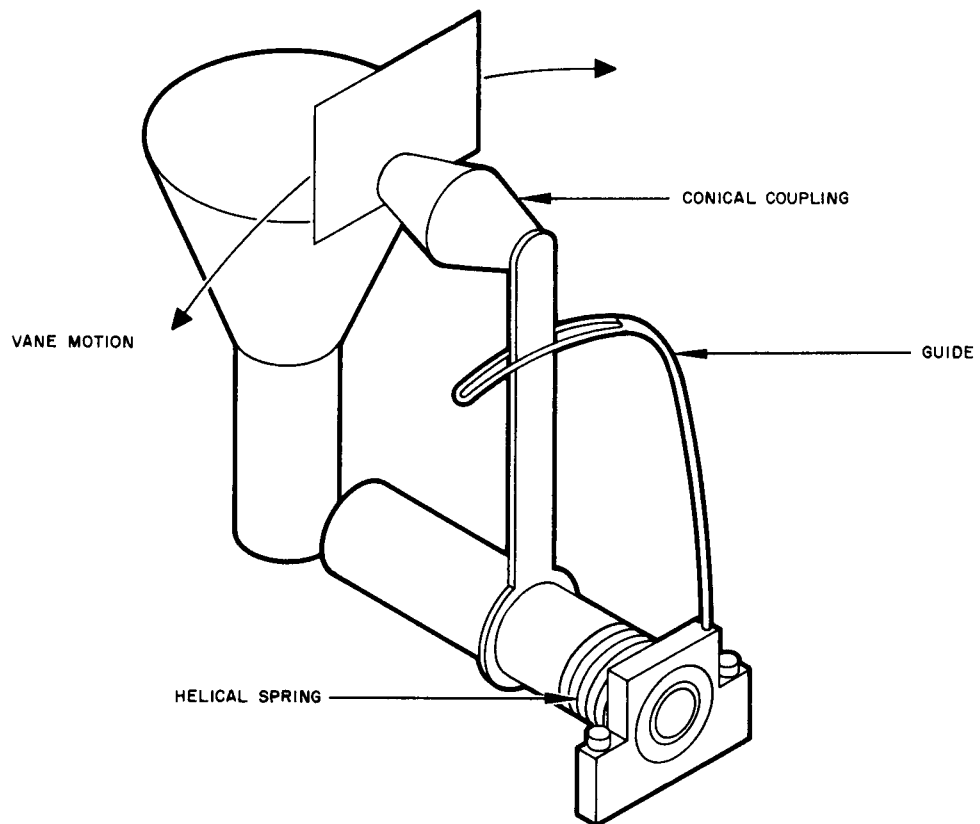


Figure 3-17. Means of Reducing Heat Transfer to Crank of Vane Mechanism

primarily by biasing of the jet from a position parallel to the spin axis and initial Agena spin-up error) indicates that the variation in the frequency ratio from the ideal could be as much as 14 percent. Therefore, design of the rotating jet should be made assuming that the worst case of amplitude reenforcement prevails.

The effect of jet oscillations less than maximum travel is to cause a bias for the spin correction torque. The largest bias would result for the case of oscillation reenforcement when the jet on-time corresponds to the width of one-half period of the jet oscillation (see Figure 3-18). For $n = 3$ this relationship almost exactly prevails. The average value of one-half a sine wave is 0.636 of the maximum. For an amplitude oscillation of ± 1 degree, the largest bias from the nominal jet position would then be 0.636 degree. Full jet travel is 8.1 degrees; therefore, the oscillation causes a bias of $0.636/8.1 \times 100 = 7.85$ percent of the spin-speed control range. For a ± 25 rpm control range the bias corresponds to about ± 2 rpm. The bias is reduced proportionally with the reduction in the maximum permissible oscillation amplitude.

A brief analog computer study was performed to determine the nature of the jet oscillation and the damping required to restrict the maximum amplitude to 1 degree for the maximum expected misalignment torque. Figure 3-19a is the response of the undamped jet to a step input. Figure 3-19b is the jet response for the case of oscillation cancelling (mechanism frequency = 3.5 times spin rate) by consecutive thrust pulses. Figure 3-19c is the jet response for oscillation reenforcement (mechanism frequency = 3.0 times spin rate). For the latter case, addition of damping equivalent to 0.1 of critical limits the amplitude to 1 degree, as seen in Figure 3-19d. A check was made of this conclusion with a Fourier analysis of the disturbing torque and the response of a second-order system to the pertinent harmonics, which were 1.67, 3.34, and 5.01 cps. An investigation is now in progress to determine whether this much damping can be obtained in a practical manner. Both eddy current and fluid damper mechanisms are under consideration.

There appears to be no heat transfer problem involved with the rotating jet mechanism, although it is attached to the structure only at the pivot point. The jet fuel injector block need only be about 0.2 pound to absorb enough heat to prevent the fuel in the tubes from reaching unsafe temperatures. Stresses in the propellant tubing will be maintained well below the maximum allowable to preclude failure of the tubing caused by the oscillation of the mechanism. The duty cycle for the axial jet is well under that of the radial jet. Less than 1000 turn-ons will be necessary, whereas the radial jet will be operated some 150,000 times.

Effort during this period has been confined to a more detailed evaluation of the two spin-speed control devices under consideration.

During the next report period, a selection and detailed design of the spin-speed control mechanisms will be performed. Environmental conditions should be available to allow an initial evaluation of the sun sensors and timers being developed for Syncom I for use on Syncom II. Analysis of the orientation maneuver will continue.

APOGEE MOTOR LIAISON

Performance specifications were completed for a solid-propellant apogee injection rocket motor. The apogee motor specification was submitted to Goddard for review and use in NASA procurement of a solid-propellant motor development program. A synopsis of the specification performance and physical requirements for the motor is given in Appendix B.

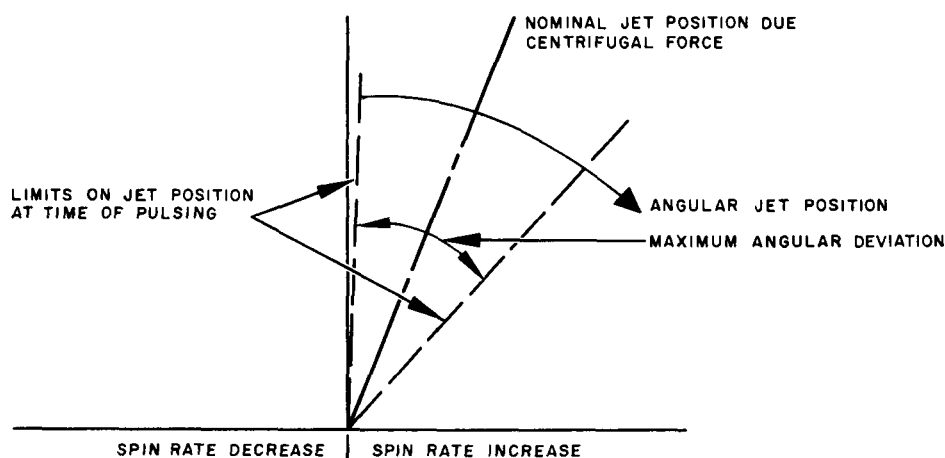
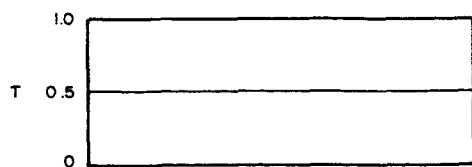
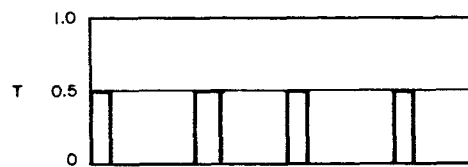


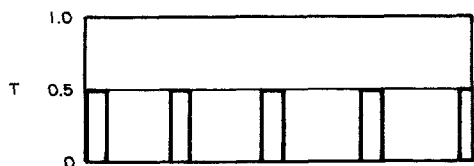
Figure 3-18. Effect of Jet Oscillations on Position Where Jet is Operated



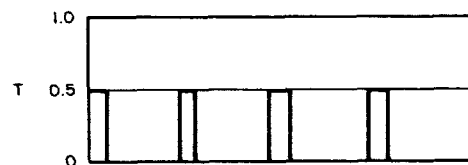
a) Step response to undamped system



b) Pulse response of undamped system for frequency $3.5 \times$ spin rate



c) Pulse response of undamped system for frequency $3.0 \times$ spin rate



d) Same as c) with exception that damping is 0.10 of critical

T = DISTURBANCE TORQUE APPLIED TO JET, INCHES-POUNDS

θ = ANGULAR POSITION OF JET FROM NOMINAL

Figure 3-19. Analog Computer Results of Effects of Various Properties on Rotating Jet Dynamic Response

4. ALTERNATE CONFIGURATION

SYSTEM STUDIES

A study is being conducted to evaluate the feasibility of a liquid-propellant apogee engine for Syncom II. The report of this study will be published in November. There are three principal parts to the study: 1) a comparative analysis of solid and liquid systems, 2) study of spacecraft dynamics with the large volume of liquid propellants required, and 3) a survey of the availability and cost of suitable liquid-propellant engines.

The first portion of the study will consider such factors as: combining tanks for engine and station-keeping system; performance in terms of injection errors and subsequent cost of correction to desired orbit; and flexibility in such areas as off-loading, static testing, etc.

The second part of the study consists in formulating a simplified fuel sloshing model to predict the spin stability behavior of two generic liquid-propellant apogee engine tank configurations: toroidal tank, the axis of which is along the spin axis of the spacecraft; and spheroidal or cylindrical (with spherical end-cap) tanks spaced circumferentially at a given radius from the spin axis. Emphasis will be placed on spin behavior during the boost period of the third stage.

The third part includes consideration of possible engine configurations which are compatible with Syncom II. Included will be performance, size and weight, cost, and availability. Engines from the following manufacturers are considered: 1) United Technology Corporation, 2) Marquardt, 3) Bell Aerosystems, and 4) Rocketdyne.

A final section of the report will consider tradeoffs between liquid-propellant motors and solid-propellant apogee engines. Recommendations will be made including a possible configuration selection. A weight report of the selected configuration will be included.

STRUCTURAL DESIGN

The layout for the alternate configuration of the combined liquid-propellant apogee engine and vernier control system with toroidal tanks has been completed (Figure 4-1).

The tankage consists of three toroidal tanks (fuel, oxidizer, and nitrogen) for the apogee motor and two redundant vernier control systems.

The structure consists of two subassemblies: forward and aft. The aft subassembly consists of a cone-shaped thrust tube made of aluminum sheet, aluminum machined rings, and eight aluminum stiffeners which are riveted inside the cone. A flat magnesium sheet (aft bulkhead) is supported by eight radial magnesium aft ribs attached at the periphery of the thrust tube. These ribs carry the weight of the three toroidal tanks and electronic packages.

The forward subassembly consists of the inner magnesium ring, forward magnesium bulkhead, and eight magnesium forward ribs. The forward bulkhead is supported by eight radial ribs attached at the periphery of the inner cylinder.

The outer cylinder is segmented into eight parts and attached to the aft ribs, longerons, and forward ribs. The segmented cylinder and the eight longerons are removable to provide access to the electronic packages.

A concentric pair of rings is welded to the oxidizer tank, and another pair to the nitrogen tank. These rings are attached to the aft bulkhead and aft ribs. The fuel tank is cantilevered from the forward end of the oxidizer tank in a similar pair of rings.

The design retains the same solar panels, vernier control jets, and sun sensors as the configuration using a solid-propellant spherical apogee injection motor.

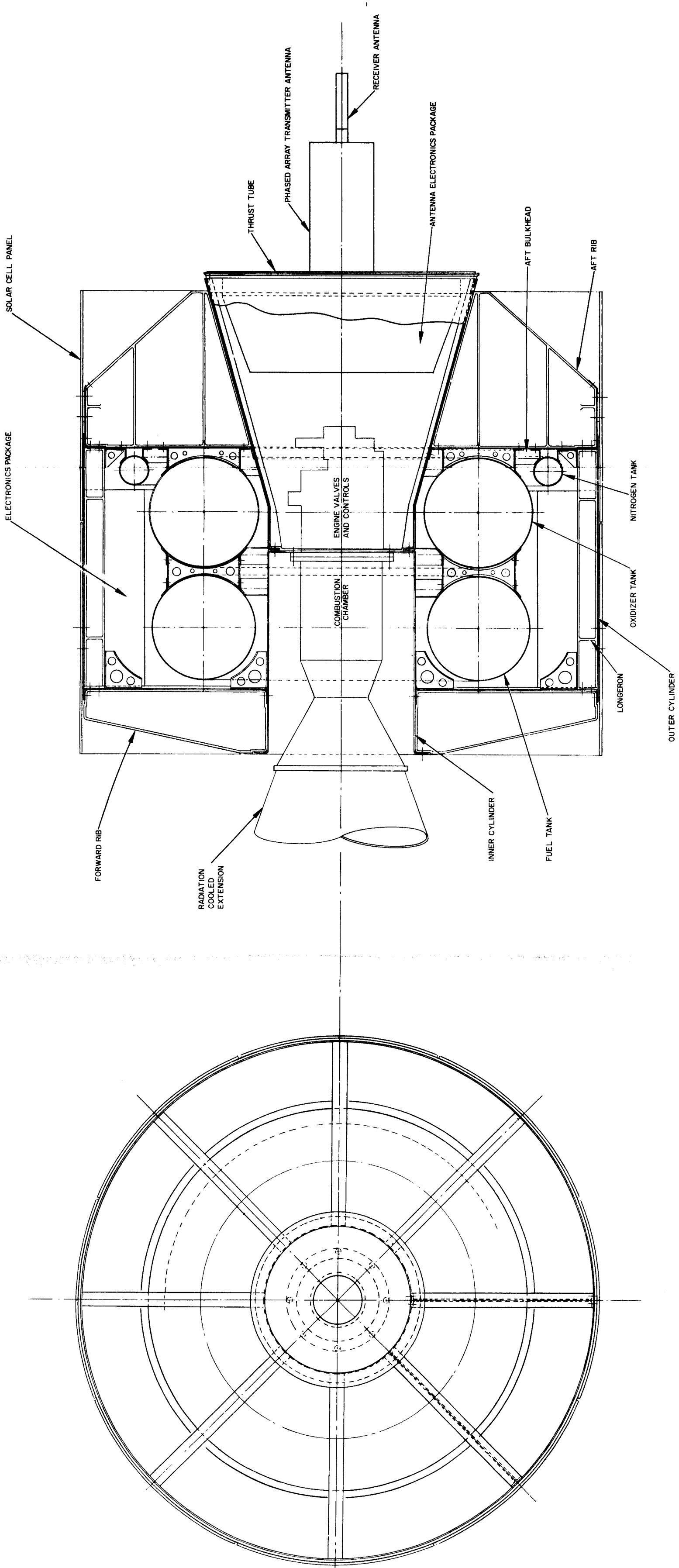


Figure 4-1. Alternate Configuration – Liquid Apogee Motor

5. NEW TECHNOLOGY

There were no items of new technology reported during the report period.

6. PROJECT REFERENCE REPORTS

- V.H. Ho, "Trip Report" - Visit to Ball Brothers Research Corporation, Boulder, Colorado, dated 15 October 1962.
- D.S. Braverman and D.D. Williams, "Single-Sideband to Phase Modulation Multiple Access Communication System Analysis," TM721, October 1962.
- "Preliminary Performance Specification, Syncom II Apogee Rocket Motor," 17 October 1962.
- "Specification No. X-254044, Performance Specification, Syncom II Bipropellant Reaction Control System," 23 October 1962.

TABLE A-1. PERFORMANCE REQUIREMENTS SUMMARY

Parameter	Rating	Three Standard Deviation Limit
Total impulse per system (two units)		
For velocity correction and orientation	That required to provide a total $\Delta V = 2300$ fps to an initial spacecraft gross weight of 575 pounds, in- cluding the weight of fully loaded system	± 1 percent
For spin rate control	600 $\text{lb}_f\text{-sec}$	± 1 percent
Thrust		
Maximum	5 pounds	± 5 percent
Minimum, at one-half initial charge pressure	3 pounds	---
Response time, maximum (0 to 95 percent thrust)	12 milliseconds	---
Decay time, maximum (full thrust to 5 percent thrust)	12 milliseconds	---
Effective specific impulse, (80 percent continuous, 20 percent pulsing)	290 $\text{lb}_f\text{-sec}/\text{lb}_m$	---
Pulse mode operation at a nominal 100 rpm		
Time ON	100 milliseconds	---
Time OFF	500 milliseconds	---

APPENDIX A. SYNOPSIS OF PERFORMANCE SPECIFICATION OF SYNCOM II BIPROPELLANT REACTION CONTROL SYSTEM

PERFORMANCE CHARACTERISTICS

The specified performance characteristics of the reaction control system are based on sea level as well as vacuum operating conditions.

Its operating regimes involve altitudes and temperatures, spin conditions, spin rate control, performance and rating limits, and total impulse. Its start characteristics requirements include the parameters of start time and start impulse. Shutdown characteristics specified are shutdown time, shutdown impulse, effective specific impulse, continuous operation, pulsed operation, and pulsed repeatability.

The mission operating sequence of the control system is: 1) the system is "armed" when the tanks are loaded with propellant, pressurized with gas, and the propellant shutoff valves are opened; 2) actuation of the thrust chamber is accomplished by a command signal from ground control equipment; 3) continuous or cyclic pulsed operation of the thrust chamber is accomplished by either a continuous or cyclic pulsed command signal for the desired period of time; 4) cessation of electrical power to the propellant on-off valves will result in closure of the valves and shutdown of the thrust chambers; and 5) when the above sequence is completed, the system will remain in a pressurized and ready state, and will be capable of many restarts and operation at any time during a 5-year orbital period.

The performance requirements are summarized in Table A-1.

PHYSICAL CHARACTERISTICS

In brief, the physical characteristics of the system contained in this specification for the two bipropellant reaction control units are: two spherical fuel/pressurant tanks 180 degrees apart; two spherical oxidizer/pressurant tanks 180 degrees apart; one thrust chamber thrusting parallel to the vehicle spin axis; one thrust chamber thrusting normal to the spin axis, with the thrust centerline passing through the vehicles center of gravity; associated manifolding; and instrumentation suitable for monitoring propellant system pressures, propellant flow rates, and temperatures.

Weight requirements within the specification are those areas of dry hardware, fluids, and pressurant gas.

The second unit will be assembled into the spacecraft so that the thrust chambers are located 180 degrees from those of the first unit.

The center of gravity of the dry reaction control system and the fully loaded system are specified. The moments-of-inertia requirements are stated. These will be determined with respect to three orthogonal axes, one of which is the spin axis. The remaining two axes will lie in a plane which passes through the centers of the propellant tanks and is normal to the spin axis. Specifications for the envelope dimensions and thrust alignment are noted in Figure A-1.

The system envelope is composed of two units: the concentric cylinder is 56 inches outside diameter by 30 inches inside diameter by 13 inches long; the propellant tank diameter (maximum) is 12 inches.

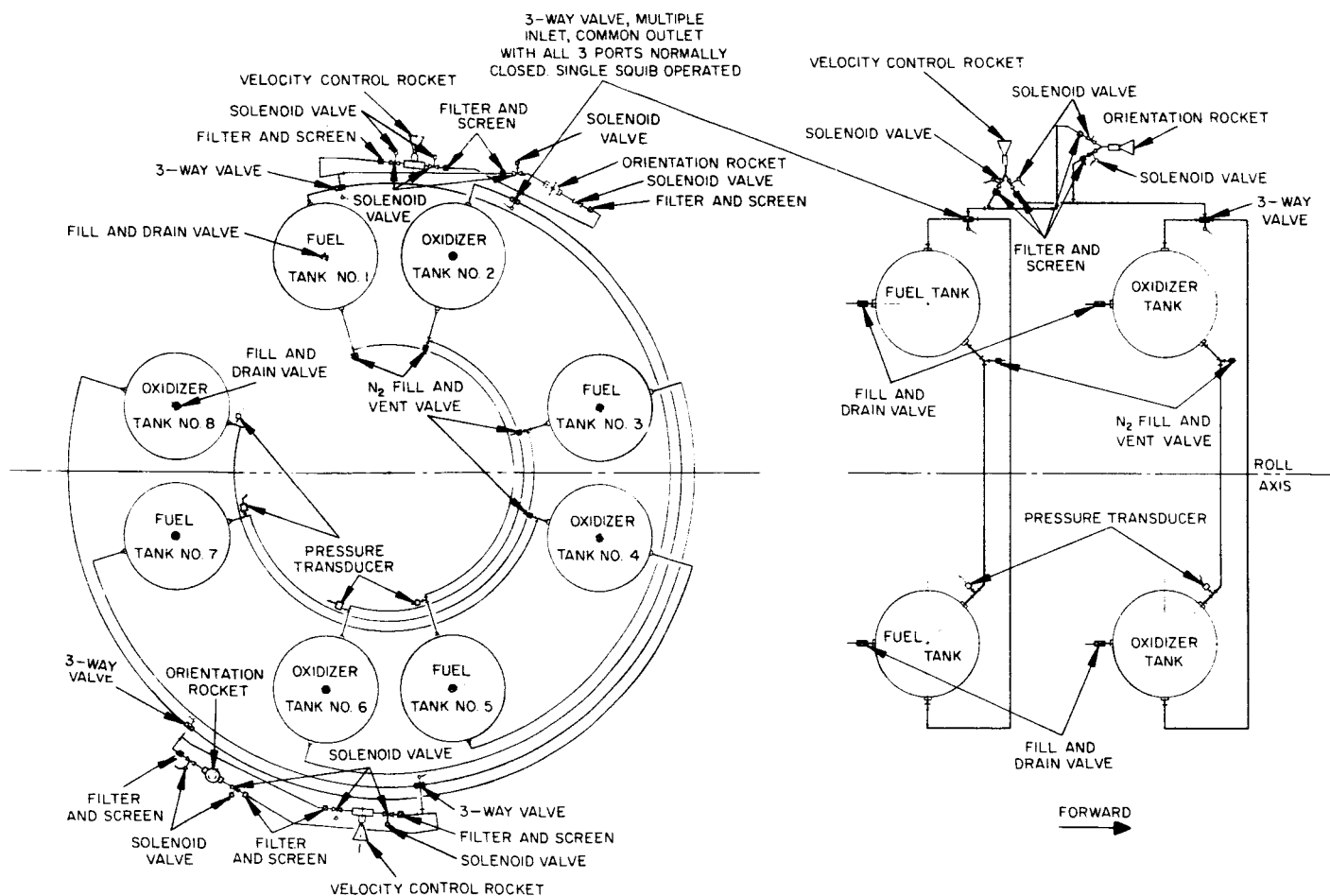


Figure A-1. Bipropellant Vernier Control System

APPENDIX B. SYNOPSIS OF PRELIMINARY PERFORMANCE SPECIFICATION OF SYNCOM II APOGEE ROCKET MOTOR

PERFORMANCE CHARACTERISTICS

The rocket motor performance characteristics are based on sea level and vacuum operating conditions and intermediate altitude test conditions. General operating regime requirements include the parameters of altitude and temperature, temperature exposure, thermal gradient conditions, attitudes, spin conditions, total impulse, thrust, action time, ignition time, and chamber pressure.

PHYSICAL REQUIREMENTS

The maximum weight of the assembled rocket motor and all components should not exceed 860 pounds; envelope dimensions are those previously defined by Hughes. The center of gravity of the empty and loaded motors will be aligned with the spin axis of the motor. The angle between the centerline of thrust and the spin axis has previously been acceptably delineated by Hughes. Thrust centerline excursion will not exceed 0.010 inch during motor burning (this will be demonstrated before and after firing determination of thrust centerline location).

All delivered motors will be statically and dynamically balanced about the spin axis. Static unbalance before loading will be less than 4.6 oz-in. Dynamic unbalance of loaded motors will be less than 138 oz-in., and the spin rate will be a minimum of 150 rpm.

The moments of inertia are specified about three orthogonal axes through the center of gravity, one parallel to the attachment axis.

The inert rocket motor and components are specified. Changes to live rocket motor features affecting spacecraft or spacecraft installation will be incorporated in the inert rocket motor.

For resonant frequency requirements, the fundamental longitudinal frequency of the rocket motor will not exceed 200 cps at the motor attachment fittings. Igniter resonance requirements are also delineated.

The rocket motor requirements are summarized in Table B-1. The maximum space envelope and mating provisions are shown in Figure B-1.

TABLE B-1. ROCKET MOTOR REQUIREMENTS SUMMARY

Parameter	Rating	Three Standard Deviation Limit
Total Impulse at vacuum		
Fully loaded	That required to provide a $\Delta V = 6009$ ft/sec to a vehicle weight of 650 pounds, exclusive of apogee motor	± 1 percent of nominal value
Maximum off loading	That required to provide a $\Delta V = 6009$ ft/sec to a vehicle weight of 500 pounds, exclusive of apogee motor	± 1 percent of nominal value
Thrust, maximum, at 100°F at vacuum	9500 pounds	---
Ignition time, maximum	0.125 second	± 0.050 second of any temperature
Action time, maximum	30 seconds	---
Weight, maximum, fully loaded	860 pounds	---
Vacuum specific impulse, minimum	285 lb _f -sec/lb _m	---

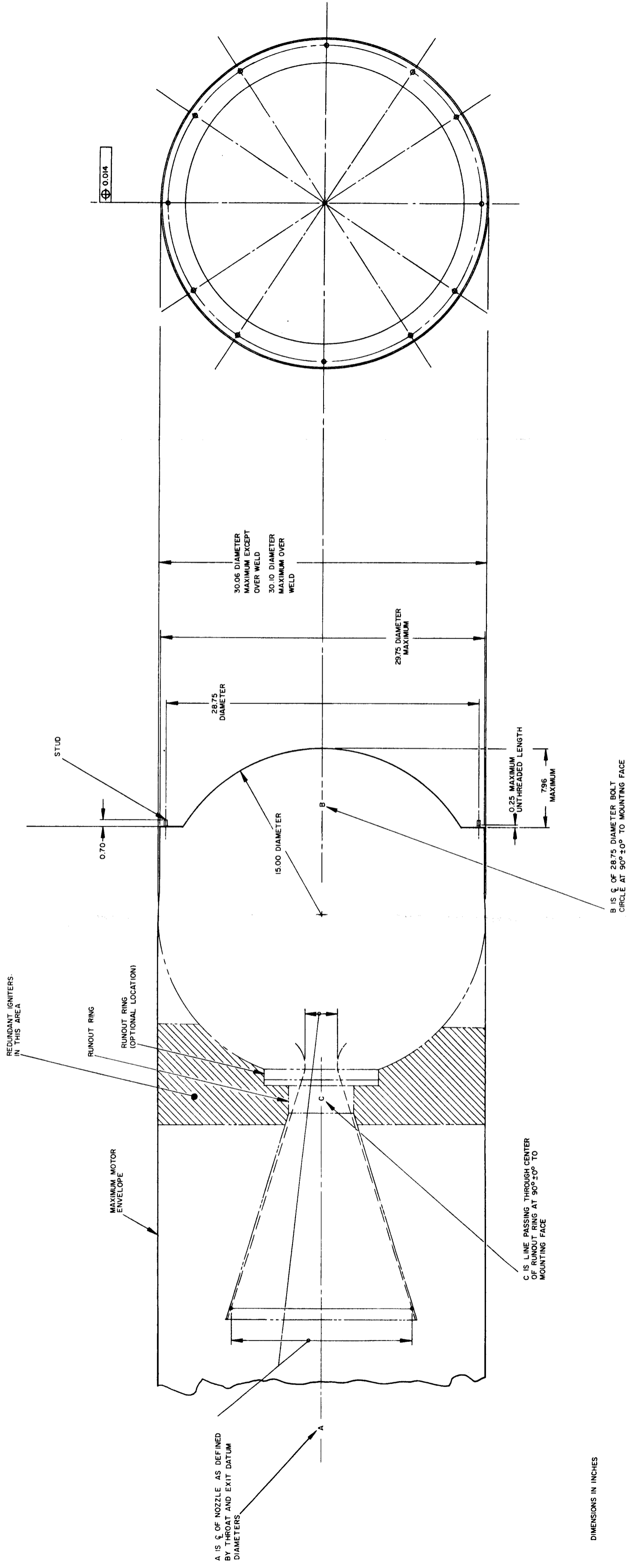


Figure B-1. Maximum Space Envelope and Mounting Provisions - Apogee Motor, Syncom Mark II